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Investment Analysis Report

Next-Generation Air/Ground Communications System

Mission Need Statement # 137

September 1, 1998

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ASD-400

Concurrence: ______________________________
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Investment Analysis Team

The Next-Generation Air/Ground Radio Communications System Investment Analysis Report was prepared by the Investment Analysis Team in the Spring of 1998 under the leadership of Vince Schultz (ASD-410), Phone 202-358-5525. To obtain a copy of this report contact George Huxhold, SETA, at 202-651-2240, or george.huxhold@faa.dot.gov.

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NEXCOM
Investment Analysis Report

Executive Summary

The FAA is considering upgrading its air/ground communications infrastructure to support both voice and data communications. This effort is driven by the need to accommodate additional circuits to support increasing demand for voice and data communications.

To support an investment decision for the Next Generation Air/Ground Communication (NEXCOM) program, the Investment Analysis & Operations Research Directorate (ASD-400) formed an Investment Analysis Team (IAT). Their objective was to recommend a preferred NEXCOM architecture and develop an Acquisition Program Baseline (APB) for review and approval by the Joint Resources Council (JRC). Many FAA organizations (AAT, AAF, AND, ARR, ASD, ATO, ACT, and ASR) participated in the analysis. In addition, a joint FAA/user/industry task group was formed to (1) review the work of the IAT; (2) ensure user and industry concerns were appropriately addressed; and (3) gain user and industry support for the preferred approach.

Background

The FAA needs air/ground communications to provide safety-critical Air Traffic Control (ATC) services. By adding additional capacity and functionality to the Air/ground Communications Subsystem of the National Airspace System, the FAA will continue to provide high quality ATC communications and accommodate future growth. The following actions must be taken:

- Provide Air Traffic (AT) controllers the capability to accommodate the growing number of sectors and services using the available limited radio frequency (RF) spectrum.
- Control logistical costs by making strategic investment in replacements for older radios.
- Provide new data link communications capability to all classes of users (Air Carriers and General Aviation).
- Provide security mechanisms to identify unauthorized users (e.g., “phantom controllers”).

The investment analysis team considered several NEXCOM architectures based on technologies that are currently used or are being proposed for use in the marketplace. The alternatives included the following ground and satellite based system architectures:

- Architectures with continued use of voice paired with a digital data system using Carrier Sense Multiple Access (CSMA) technology.
- Architectures based upon an international aviation standard ground-based digital integrated data and voice (ASIDV) system, or a commercial standard ground-based digital integrated data and voice (CSIDV) system.
  - ⇒ The ASIDV system employs Time Division Multiple Access (TDMA) technology in the VHF band.
  - ⇒ The CSIDV system employs Code Division Multiple Access (CDMA) technology in the VHF band.
- Satellite based architectures using either a Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) Mobile Satellite Service (MSS), or Geosynchronous Earth Orbit (GEO) service.

A Request for Information was published to solicit industry comment on the above architectures and to stimulate suggestions for additional innovative solutions.

Next-Generation Air/Ground Communications System

The team established a set of evaluation criteria and developed a model to use with the Expert Choice™ (EC) decision support software program to perform an Analytic Hierarchy Process to evaluate the candidate architectures. The high-level evaluation criteria are shown in the table below. Information gained from the Request for Information, other technical and economic analyses, and engineering judgment were used as inputs to the decision support model. Outputs from the model were combined in a red/yellow/green display to show a high level assessment of each alternative according to the established criteria.

Overall ranking of the six candidate alternatives (plus the baseline current system) are shown below with numerical ratings for technical and risk and color coded ratings for schedule, transition/integration, cost and supportability. A **"Green (G)"** rating indicates a high probability of compliance with given criteria. A **"Yellow (Y)"** rating means that a level of uncertainty exists regarding compliance with given criteria. A **"Red (R)"** rating means that there is a high probability that the factor does not comply with given criteria.

Overall Assessment of Alternatives

		Evaluation Criteria / (Weights)					
Alternatives	Overall Rank	Technical (.45)	Risk (.15)	Schedule (.15)	Transition (.15)	Cost (.05)	Supportability (.05)
ASIDV	1	0.984	0.889	G	Y	Y	G
25/SDN	2	0.777	0.778	G	G	G	G
8.33/SDN	3	0.822	0.611	G	Y	Y	G
CSIDV	4	0.914	0.750	Y	Y	Y	G
GEO	5	0.789	0.361	R	Y	Y	Y
LEO/MEO	6	0.650	0.361	Y	Y	R	Y
CURRENT		0.691	0.972	G	G	G	G

Based on the above, the team recommends an international aviation standard ground-based digital integrated data and voice (ASIDV) radio system employing Time Division Multiple Access (TDMA) technology in the VHF band as the preferred alternative.

NEXCOM Development Approach

For purposes of affordability, ease of transition and risk reduction the IAT proposes that the NEXCOM acquisition be accomplished in three segments, each separate and distinct with respect to delivery of benefits, and each building upon the previous segment. Segment One (2002 - 2008) provides an initial operating capability (IOC). Segment Two (2005 - 2010) adds functionality to the system to meet all requirements of the NEXCOM system specification and Segment Three (2010 - 2015) expands deployment of NEXCOM to terminal areas. Specific goals and definitions for each segment are listed in the table on Page iii.

Next-Generation A/G Communications System Goals and Definitions

Term	Definition	IOC	FOC
Segment One	Deploy new digital radios to super high and high en route sectors. Transition to digital voice in super high and high en route sectors beginning in 2005 and completing by 2008.	2002	2008
Segment Two	Complete deployment of new digital radios to remaining sites. Begin transition to provide Data link Capability (CPDLC) in super high and high en route sectors. Superhigh and high data will be operational by 2010.	2005	2010
Segment Three	Complete transition of high-density terminal areas (57 airports) to digital voice and data.	2010	2015

Major Assumptions, Constraints, and Conditions

The major assumptions underlying this analysis include the following:

1. Life cycle costs and benefits need to be shown over a period of 23 years (from 1998-2020) because of the way the program is segmented.
2. All NEXCOM VHF radios must be capable of analog and digital voice during the transition period (2005 - 2008); and digital voice integrated with data at the end-state (2010-2015), i.e. multimode.
3. Six radios are necessary to support one ATC A/G frequency for a sector. The six pieces of equipment include one main receiver, one standby receiver, one main transmitter, one standby transmitter, one backup emergency transmitter, and one backup emergency receiver.
4. The current FAA Frequency Assignment database has approximately 1,060 assignments for approximately 800 en route sectors. Based on assumption 3 above 6,360 radios are the *most likely* number of radios needed to convert all Remote Control A/G (RCAG) radios.
5. The growth rate of NAS circuit assignments is 4% per year. This growth rate includes A/G expansion projects as well as assignment growth resulting from other programs such as Towers, Terminal Radar Approach Control (TRACON) and base closures.
6. A dedicated one-for-one back-up emergency communications architecture will be in place prior to NEXCOM deployment.
7. All aircraft that currently use VHF analog communications in the high en route airspace will be required to equip with digital radios.
8. The allocated air/ground communications bandwidth will remain in place. Only an increase in available circuits per frequency will be realized.

Economic Analysis Segment One

The NEXCOM economic analysis focuses on FAA and user life cycle costs and benefits, net present value, and benefit cost ratio. All figures are expressed in current dollars or 1998 present value dollars, whichever is appropriate for the analysis. The economic analysis is based on “most likely” input values, though the inputs for many of the cost and benefit categories have a range of values due to uncertainty. Risk assessment is a technique that captures the impact of that uncertainty. The cost and benefit estimates in the following paragraphs reflect the results of the risk assessment.

Next-Generation Air/Ground Communications System

FAA Costs

Facilities and Equipment (F&E) costs for A/G communications include NEXCOM Segment One implementation costs to support digital voice communications in the high and super-high en route sectors and expansion/sustainment costs to support parts of the current A/G system that are not involved in Segment One (low en route, Terminal and Flight Service). Implementation costs consist of radios, radio interface units (RIUs), Radio Control Equipment (RCE), linear power amplifiers (LPAs), spare parts, and other costs to replace current ground radios and equipment in the affected sectors. Expansion/sustainment costs are for radios, RIUs, RCE, LPAs, and other costs required to modernize low en route, Terminal and Flight Service A/G communications at co-located sites that support more than just the high and super-high en route sectors. Modernizing an entire multi-purpose site is expected to save costs in the long term. F&E costs are also required to support analog legacy radios until they can be replaced with NEXCOM radios.

The cost profiles shown below assume current Communications Facilities Enhancement (CFE) requirements are funded as shown in the NAS Architecture Baseline dated April 1, 1998. Changes to the current CFE funding profile will require a corresponding adjustment to the NEXCOM baseline because responsibility for CFE costs to maintain the current system is transferred to NEXCOM beginning in 2005. This is shown in the Expansion/sustainment line in the table below. Responsibility for O&M costs to sustain RCE, LPAs, and emergency transceivers, is also transferred to NEXCOM, beginning in 2002.

Costs shown in gray support A/G legacy systems, and are not part of the NEXCOM Segment One baseline. The NEXCOM program baseline assumes these costs are funded at their current level. Costs through FY01 are required whether or not NEXCOM is approved.

The table below illustrates A/G communications costs at the 80 percent confidence level:

A/G Communications Costs, including NEXCOM Segment One (Current $M)

	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09-20	Total
F&E	**14.3**	**11.6**	**36.6**	**64.9**	**88.7**	**86.8**	**78.0**	**71.2**	**63.6**	**44.0**	**26.5**	**33.2**	**619.3**
NEXCOM Segment One	2.2	0.5	10.1	24.2	54.6	51.9	48.3	57.7	56.0	41.5	25.2	0.0	405.5
Implementation	*2.2*	*0.5*	*10.1*	*24.2*	*46.6*	*43.8*	*40.0*	*39.5*	*37.4*	*22.5*	*5.8*	*33.2*	*305.9*
Expansion/ Sustainment	*0.0*	*0.0*	*0.0*	*0.0*	*8.0*	*8.1*	*8.3*	*18.2*	*18.6*	*19.0*	*19.4*	*0.0*	*99.6*
Legacy*	12.1	11.1	26.5	40.7	34.1	34.8	29.7	13.5	7.5	2.6	1.3	0.0	213.9
O&M	**95.1**	**98.6**	**100.8**	**105.3**	**106.6**	**110.2**	**113.6**	**118.9**	**126.5**	**131.2**	**135.7**	**1810.1**	**3052.6**
NEXCOM Segment One					106.6	110.2	113.6	118.9	126.5	131.2	135.7	1810.1	2652.8
Sustainment #	95.1	98.6	100.8	105.3									399.8
Total	**109.5**	**110.2**	**137.4**	**170.2**	**195.3**	**197.0**	**191.6**	**190.1**	**190.1**	**175.2**	**162.2**	**1843.3**	**3672.1**

*/ Legacy = Current AND-340 programs; #/ Sust. = O&M to support Legacy Sustainment

User Costs

User life cycle costs include costs for avionics, installation, upgrades, spares, certification, re-certification and down time. All costs were calculated based on the following assumptions:

- Life cycle of avionics is 15 years.
- Military aircraft will replace current analog VHF radios with VHF digital radios but will not replace UHF radios.
- For data link applications, digitally capable aircraft can use current cockpit display units and software upgrades for current communications management units (CMU's).
- Non-digitally capable aircraft will require new cockpit display units and new CMU's for data link applications.
- User community will require at least five years lead-time to equip. Air carriers are not expected to incur additional out-of-service time beyond regular maintenance cycles.
- GA aircraft that are not currently radio equipped will not equip with VHF digital radios.
- Beginning in the year 2003, new aircraft will come equipped with VHF digital radios and the cost for such equipage is not included in this analysis.

User Life Cycle Costs (Current Year $M)

	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11-20	Total
User	0.0	0.0	0.0	0.0	0.0	165	169	172	176	118	37	38	39	436	1352

Benefits

NEXCOM will provide increased spectrum capacity, reduce circuit blockage, and reduce risks from unauthorized access. It will provide ATC the capability to accommodate the growing number of sectors and services, as well as "free flight" by increasing the number of voice circuits available within the current VHF ATC spectrum. Additionally, NEXCOM provides a data link communications capability to all classes of users within a single integrated digital- voice/digital - data equipment.

NEXCOM can benefit users by:

- Providing circuits for additional operator positions to support new runways, thereby reducing ground and airborne delays in the terminal area;
- Provide increased capacity by making additional frequencies in the en route environment available for implementing new sectors leading to reduced delays;
- Providing additional air traffic services such an Automated Weather Observing System (AWOS) and Automated Surface Observing System (ASOS) due to the availability of additional frequencies.

Next-Generation Air/Ground Communications System

Most Likely NEXCOM User Benefits (Current $M)

Benefit Driver	Benefit Metric	Economic Benefit
Reduced ground and airborne delays	Runways implemented at major airports that have severe traffic congestion (i.e., Atlanta, Cleveland, Minneapolis, and Charlotte)	$1,422 M
Reduced delays in the en route environment	New sectors can be implemented.	$36 M
Total User Economic Benefit		**$ 1,458M**

Net Present Value and Benefit/Cost Ratio

The two economic measures that are generally referenced when making an investment decision are Net Present Value (NPV) and Benefit/Cost (B/C) Ratio. The NEXCOM economic analysis is summarized in the following table.

Range of Estimates at the 20/80% and 80/20% Confidence Levels

NEXCOM	Range	Most Likely
COSTS		
FAA F&E (Current $)	610 - 619	618
FAA OPS (Current $)	3032 - 3053	3042
User Avionics (Current $)	1190 - 1352	1281
Total Costs (Current $)	4,692 - 5,160*	4,941
Total Costs (Constant $1998)	3,735 - 4,098	3,927
PV Total Costs	2,041 - 2,213	2,136
PV Incremental Costs	361 - 452	415
BENEFITS		
Benefits (Current $)	1,458 - 2573	2,049
Benefits (Constant $1998)	1,052 - 1,830	1,457
PV Benefits	383 - 666	530
NPV	(28) - 264	115
B/C Ratio	0.9 - 1.7	1.3

* 20/80 and 80/20 confidence totals are based on Monte Carlo simulation and therefore are not additive.

Affordability Assessment

The NEXCOM Acquisition Program Baseline (APB) was briefed to the Systems Engineering Operational Analysis Team (SEOAT) on May 1, 1998. At the meeting, the SEOAT decided that the NEXCOM APB was affordable under the current agency budget baseline.

Requested JRC Actions

The NEXCOM IAT requests the following from the JRC:

- Reaffirm the need for the NEXCOM program initiative.

- Affirm the recommendation for TDMA VDL Mode 3 as the preferred alternative for NEXCOM Segment One.
- Affirm the segmentation approach to the NEXCOM program.
- Approve the Investment Decision for NEXCOM Segment One.
- Approve the proposed APB (*Acquisition Program Baseline Next Generation Air/Ground Communications System (NEXCOM), Preferred Alternative Segment One*).
- Assign the NEXCOM program to the Communications IPT for implementation.
  - ⇒ The Communications IPT will provide a NEXCOM representative to DoD and have their representative participate on NEXCOM with the Communications IPT.
  - ⇒ The Communications IPT will work with DoD to finalize a Memorandum of Understanding and/or Memorandum of Agreement.

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NEXCOM IAR

1. Introduction

The investment analysis report (IAR) represents the primary decision document to support the Joint Resources Council (JRC) Investment Decision for the Next-Generation Air/Ground Radio Communications System (NEXCOM). This IAR documents activities conducted by the NEXCOM Investment Analysis Team (IAT) that led to the development of the *NEXCOM Investment Analysis Report* (IAR) and *Acquisition Program Baseline* (APB). As specified in the *Acquisition Management System Investment Analysis Process Guidelines,* this report summarizes the mission need, requirements, assumptions, economic assessment, and risks of the program. The report also documents the results of the affordability assessment conducted by the System Engineering Operational Analysis Team (SEOAT). Finally, the report summarizes IAT recommendations to the JRC for implementing a digital-based integrated voice and data, very high frequency (VHF) Air/Ground (A/G) communications capability in the National Airspace System (NAS).

Federal Aviation Administration (FAA) policy to transition from the current analog A/G radio communications system to a digital-based system has been stated in several FAA documents. These include the *1997 Aviation System Capital Investment Plan*, and the *National Airspace System Architecture*.

1.1. Background

Since the 1940's, increased demand for additional controller-pilot circuits have been met through "circuit splitting" or decreasing the separation between circuits. The VHF band assigned to the FAA for Air Traffic Control (ATC) communications is fixed by international agreement. No attempt has been made to seek spectrum or circuits outside this band in part to minimize the impact on users by avoiding the need to transfer "out of band." As the spacing has decreased from 200 kilohertz (kHz) to 100 kHz, to 50 kHz, and to the present 25 kHz, problems caused by co-siting and intermodulation have increased, thereby limiting the effective capacity gain of the system associated with the decrease in channel spacing. The VHF band used for ATC is between 117.975 and 137 megahertz (MHz) range. This equates to 760 different 25-kHz circuits that can be assigned of which 527 circuits are available to the FAA for ATC. Because VHF is line-of-sight, circuits can be re-used across the NAS, but there are many constraints on this re-use. As of January 1998, the current number of FAA assigned VHF A/G circuits is 11,450. In many areas, insufficient frequency resources exist to allow reuse due to interference constraints. The lack of interference-free frequencies is causing delays and constraining NAS capacity.

On July 6, 1995, the Transportation Systems Acquisition Review Council (TSARC), recognizing the need to expand spectrum capacity, approved *Mission Need Statement # 137, Next-Generation A/G Communication System*. On November 1, 1996, the FAA formally established a NEXCOM IAT. The objective of the IAT was to quantify the extent of the spectrum problem, determine when the FAA has to take action, and define the consequences if the FAA does not take action. Based on an initial operational performance analysis, an investment analysis strategy was developed and presented for approval at an initial JRC on July 24, 1997. The July 1997 JRC approved the concept of moving to a digital air/ground communications system, and concurred with the proposed investment analysis strategy.

Following the initial JRC, five mini-teams were formed to complete the investment analysis. These were the Maintenance, Requirements, Spectrum, Alternatives Analysis, and Transition Teams.

The objective of the Maintenance Team was to determine if the current A/G communications system was failing, and how much longer the current system could be supported. Results of the Maintenance Team efforts are documented in a report titled *NEXCOM Maintenance Report*.

The objective of the Requirements Team was to provide an assessment of the future radio frequency communications system requirements. Their efforts are documented in reports titled *NEXCOM Initial Requirements Document* and *NEXCOM Requirements Document.*

The objective of the Spectrum Team was to provide an assessment of the current radio frequency communications system, and estimate the time frame for which a critical frequency resource shortfall will occur. Their efforts are documented in a report titled *NEXCOM Spectrum Requirements Report*.

The objective of the Alternatives Analysis Team was to evaluate possible solutions to the problems defined by the Maintenance and Spectrum Teams, and to recommend a preferred alternative. Results of the Alternatives Analysis Team efforts are documented in a report titled *Alternative Analysis for the Next Generation Air/Ground Communications System (NEXCOM).*

The objective of the Transition Team was to define a transition strategy for implementing the preferred alternative, and to predict the implementation costs. Results of the Transition Team efforts are documented in a report titled *NEXCOM Transition Team Report*.

The NEXCOM supplemental reports can be retrieved via SETA document control (DOCCON).

On May 5, 1998, the results of the NEXCOM investment analysis and the recommendations of the IAT were presented to the FAA JRC.

1.2. IAT Recommendation

To meet the demand for additional voice circuits by achieving increased spectrum efficiency, the Integrated Product Team (IPT) recommends that the next-generation radio system consist of multimode[1] radios. Time Division Multiple Access (TDMA) technology, which maintain the current 25 kHz frequency spacing, provides four time-slot circuits in the same frequency bandwidth. TDMA technology provides the capability to provide controller-pilot data link communications to all users, air carriers as well as General Aviation (GA). The multimode radio is backwards compatible with the current radio system, and TDMA technology provides increased radio security, improved voice quality, reduced circuit congestion, automatic circuit management, and discrete addressing.

1.3. Requested JRC Actions

The NEXCOM IAT requests the following from the JRC:

- Reaffirm the need for the NEXCOM program initiative.
- Affirm the recommendation for TDMA VDL Mode 3 as the preferred alternative for NEXCOM Segment One.
- Affirm the segmentation approach to the NEXCOM program.

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[1] Mulitmode Radio as used for NEXCOM means the radio is capable of analog and digital communications. The radio would include analog voice, digital voice, data or digital voice and data modes.

- Approve the Investment Decision for NEXCOM Segment One.
- Approve the proposed APB (*Acquisition Program Baseline Next Generation Air/Ground Communications System (NEXCOM), Preferred Alternative Segment One*).
- Assign the NEXCOM program to the Communications IPT for implementation.
  - ⇒ The Communications IPT will provide a NEXCOM representative to DoD and have their representative participate on NEXCOM with the Communications IPT.
  - ⇒ The Communications IPT will work with DoD to finalize a Memorandum of Understanding and/or Memorandum of Agreement.

The JRC approved all requested actions.

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2. Mission Need, Benefits, and Requirements

2.1. Mission Need

Mission Need Statement # 137, Next-Generation A/G Communication System, describes the current radio communications capability shortfalls and the corresponding effect on capacity, safety and supportability. The NEXCOM Mission Need Statement (MNS) focused on four primary areas:

- Provide Air Traffic (AT) controllers the capability to accommodate the growing number of sectors and services using the available, limited radio frequency (RF) spectrum.
- Reduce logistical costs (supplies, maintenance, training, etc.), i.e., replace expensive to maintain VHF and Ultra High Frequency (UHF) radios that are of the 1940s technology and have exceeded their life expectancy by 10 years.
- Provide new data link communications capability to all classes of users.
- Reduce A/G RF interference and provide security mechanisms to identify unauthorized users (e.g., “phantom controllers").

The IAT determined that the need for additional spectrum is the early driver for the NEXCOM program. Results of the need analysis conducted by the IAT are documented in two reports: *NEXCOM Spectrum Requirements Report* and *NEXCOM Maintenance Report*.

2.2. Benefits

Benefit categories for NEXCOM are: reduced delays in the terminal environment, reduced delays in the en route environment, avoided analog radio maintenance costs, increased safety, increased security, and increased capacity.

2.2.1. FAA Benefits

The FAA will benefit in the long term from avoided costs of maintaining the analog system, because NEXCOM equipment replaces a major portion of the existing A/G communications radio systems. However, the avoided costs of maintenance will not begin to accrue until after Segment One. In addition, NEXCOM can support voice and data communications within a single ground communications system.

The IAT noted that spectrum is often a critical factor in other programs achieving the benefits for which they were designed. Programs such as Precision Runway Monitor (PRM), Automated Surface Observation System (ASOS), Automated Weather Observation System (AWOS), Local Area Augmentation System (LAAS), Data Link, etc., cannot achieve full benefits unless spectrum is available to communicate information to pilots and/or controllers. NEXCOM will make additional spectrum available for these programs.

2.2.2. User Benefits

User benefits were calculated as the avoided costs of delays in the en route sectors and terminal areas and consisted of extra fuel burned and other direct operating costs.

Delays resulting from congestion in en route sectors can sometimes be avoided by sub-dividing an individual sector into two sectors or more (resectorization) and adding additional controllers to handle the workload. Resectorization reduces congestion but requires frequencies be available to allow for additional controller positions.

Delays resulting from congestion in terminal areas can be avoided by activating new runways and runway modifications as identified in the *FAA 1996 Airspace Capacity Enhancement Plan*. If the required frequency assignments are not available to support the new runways, then capacity benefits that would be attained through the new runway are assumed to be unavailable. The FAA Spectrum, Policy and Management (ASR) office's Frequency Data Base was used to evaluate whether frequency assignments were available to support the required operational positions for new runways.

Safety benefits, from a possible reduction of operational errors (OEs), near midair collisions (NMAC), pilot deviations (PDs), and other similar problems were identified and analyzed. In addition, safety benefits resulting from increased security (i.e., intentional and unintentional interference) were identified and analyzed. Both FAA and user representatives acknowledged safety benefits but these benefits were not quantified because there is insufficient data to substantiate the value of improved communications towards reducing accidents.

A detailed discussion of how these costs and benefits were calculated and applied is contained in Section 4, NEXCOM Economic Analysis.

2.3. NEXCOM Requirements

The FAA requires A/G communications in order to provide ATC services.[2] VHF and UHF radio A/G communications links are needed for all phases of flight: from coordinating movements on the airport surface, to coordinating departures and arrivals in the terminal, and en route phases. In addition, A/G communications links are needed to provide flight services via Automated Flight Service Stations (AFSSs). Functionally, the need for A/G communications includes requirements to ensure aircraft separation, to transmit instructions and clearances, for hand-offs, and to provide weather services and pilot reports.

2.3.1. Data Capability

The current mode of communications is primarily voice, but future communications media must be capable of supporting data link communications. Data capability will enable weather data, flight plan/flight management information, and ATC operations to be sent directly to the cockpit. The additional circuit capacity gained from digital technology will enable services such as automatic terminal information service (ATIS) and automated weather broadcasts to be implemented at airports where this service is unsupportable due to frequency limitations.

2.3.2. Compatibility with Existing Systems

Avionics standards and certification for aircraft are determined by the appropriate Federal Aviation Regulation (FAR) and for the class of airspace in which it operates. Air carriers have the most extensive avionics suites, followed by regional, commuter, and corporate aircraft. Avionics for GA are determined by individual pilot need. Visual Flight Rules (VFR) require a different level

[2] Bibliography 7, NEXCOM Spectrum Requirements Report

of avionics equipage than flights that operate under instrument flight rules (IFR) and in Class B[3] airspace. NEXCOM must support air carrier and GA A/G communications requirements.

NEXCOM must be able to operate within the current VHF radio networks, worldwide. NEXCOM must be based on VHF digital link standards defined by the International Civil Aviation Organization (ICAO), and provide compatible interfaces with voice switches and aeronautical telecommunications network elements at control facilities.

NEXCOM equipment must utilize the NAS Infrastructure Management System (NIMS). NIMS is an Airway Facility (AF) national system that uses remote monitoring of the performance and status of NAS equipment, and provides some remote maintenance and control of monitored equipment. The NEXCOM Product Team continues coordination with the NIMS Product Team to ensure NIMS monitoring requirements and interface responsibilities are identified and assigned.

The *NEXCOM Transition Team Report* addresses AF implementation needs.

2.3.3. Voice and Data Security

To decrease the risk of unauthorized use of assigned ATC communications frequencies, mechanisms to increase the levels of security within the VHF communications system are required. NEXCOM must support required civil aviation services and provide appropriate levels of protection against unauthorized users (phantom controllers). The current analog radio system does not provide security mechanisms necessary to deter unauthorized use, whereas, a digital radio system can take advantage of security mechanisms inherent in the digital technology. The NAS information security engineering process will identify security provisions and countermeasures to be incorporated in the NEXCOM system design.

2.4. DoD Interoperability Issues

The Department of Defense (DoD) was represented on the NEXCOM IAT, and the NEXCOM Product Team will continue the dialog with DoD.

FAA is coordinating the issues below with the DoD:

- Feasibility/practicality of joint radio program with DoD.
- DoD aircraft communications avionics equipage plans.

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[3] Airspace from the surface to 10,000 feet mean sea level surrounding the nation’s busiest airports in terms of airport operations or passenger enplanements. The configuration of each Class B airspace area is individually tailored and consists of a surface area and two or more layers, and is designed to contain all published instrument procedures once an aircraft enters the airspace. An ATC clearance is required for all aircraft to operate in the area, and all aircraft that are so cleared receive separation services within the airspace. The cloud clearance requirement for VFR operations is “clear of clouds.”

- DoD requirement for continued FAA support for DoD communications in the UHF spectrum.
- Impact of NEXCOM on DoD air traffic control and military radar unit facilities.
- Military base closures and transfer to civilian control.

3. Alternatives Analysis

The NEXCOM Alternative Analysis Team was charged with developing evaluation models, evaluating proposed architectures, and recommending a preferred alternative. Section 3 summarizes the efforts of the Alternative Analysis Team. A detailed report of the team's work can be found in a report titled: *Alternative Analysis for the Next Generation Air/Ground Communications System (NEXCOM)*.

3.1. Assumptions and Requirements

The recommended alternative must satisfy the following requirements:

- Satisfy ATC requirements as specified in the Requirements Document (RD).
- Provide an increase of voice circuits to ease spectrum congestion.
- Enable ability to add additional voice channels in the air by 2005.
- Provide an ability to maintain the current air ground communications system.
- Incorporate an integrated data link functionality in a single ground system and avionics equipment.
- Minimize user impact through a smooth tranistion.

All feasible candidate architectures were evaluated without establishing absolute minimum requirements that would exclude a specific architecture.

3.2. Candidate Summary

NEXCOM architectures were considered based on technologies in use, or proposed for use, in the marketplace. Both ground and satellite based system architectures were included.

The following alternatives were evaluated:

Current — The current analog VHF DBS amplitude modulation (AM) A/G system for voice, with no data capabilities. The current system uses 25 kHz spacing between circuits.

25/SDN — The current analog double sideband (DSB) AM A/G system with 25 kHz circuit spacing, plus a separate data-only network (SDN). The VDL Mode 2 system was evaluated as the SDN for the analysis. VDL Mode 2 employs Carrier Sense Multiple Access (CSMA) technology.

8.33/SDN — An analog DSB AM A/G system with 8.33 kHz circuit spacing, plus a SDN. The VDL Mode 2 system was evaluated as the SDN for the analysis.

ASIDV — An international ground-based digital aviation standard integrated data and voice (ASIDV) radio system that could be implemented in the early to middle part of the 2000-2009 decade. For evaluation purposes, the team assumed a VDL Mode 3 system employing TDMA technology in the VHF band.

CSIDV — A ground-based digital commercial standard integrated data and voice (CSIDV) radio system with proposed modifications for air traffic control. This system would use the VHF band. The team evaluated an architecture based on the Interim Standard 95 (IS-95) mobile telephone system defined by the Telecommunications Industry Association. IS-95 employs Code Division Multiple Access (CDMA) technology.

Mobile Satellite Service (MSS) — Either Low Earth Orbit (LEO) or Medium Earth Orbit (MEO). Depending on the particular design, LEO/MEO systems use the MSS frequency allocations (e.g., L- and S-Band) for mobile links; the fixed satellite service band (e.g., C- or Ku-Band) for fixed and satellite telemetry, tracking and command (TT&C) links; and either TDMA or CDMA for multiple access. For the purposes of this report, the team used state-of-the-art LEO systems currently under development as the basis for evaluating the LEO/MEO.

GEO — Geostationary Earth Orbit (GEO) satellite system with a new design for air traffic control. This system would use L-Band for the mobile user links and C-, X- or Ku-Band for TT&C and links to the fixed users. The team assumed that the GEO architecture would employ Global System for Mobile (GSM) communications technology using a TDMA format.

The IAT solicited industry comments on the above architectures by publishing a Request for Information. The Request for Information was also intended to stimulate suggestions for additional innovative solutions. The responses were used during evaluation of alternatives.

3.3. Evaluation

The Alternative Analysis Team used the Expert Choice™ (EC) decision support software program to evaluate the candidate architectures. Information gained from the request for information, other technical and economic analyses, and engineering judgment were used as inputs to the decision support model. Outputs from the model were combined in a red/yellow/green display to show a high level assessment of each alternative according to the established criteria. The overall assessment is shown in Section 3.3.4.

The Analytic Hierarchy Process (AHP), as implemented in the Expert Choice™ decision support software program, was used as a tool to help evaluate candidate architectures. AHP is based on a multi-level criteria structure. Criteria were grouped into categories and sub-categories to structure the model within the constraints of EC, and to help allocate weights more objectively. Weights were assigned based on a consensus of expert opinion. Higher level categories were defined first followed by their subcategories. Three separate EC models were created: technical, risk, and an overall evaluation model to determine a preferred alternative. The overall evaluation model incorporated the results of the technical and risk models, as well as, cost, schedule, transition, and supportability.

EC gives the user a choice of two approaches for constructing a decision model. The “absolute model” approach was chosen which assigned scores to each alternative, based on their inherent attributes.

3.3.1. Technical Model

Criteria selected for the Technical Model included 52 requirements listed in the Functional Requirements Matrix (FRM) from the *Requirements Document for Next Generation Air/Ground Communications System (NEXCOM) Segment One,* and one requirement from the Request for Information questionnaire. The requirements were grouped by functions (shown in Table 3-1) into six Level 1 categories, and a number of Level 2 categories. Weights were assigned to the 53 criteria using the following guidelines:

- Maintaining current functionality was weighted more than other Level 1 categories because this is the minimum requirement to gain ATC acceptance.

- The mission need statement identified "lack of system capacity" as the main deficiency in the current system; therefore, "voice capacity" was weighted significantly higher than any other technical requirement.
- Requirements identified as "key parameters" in the initial requirements document were weighted more than non-key parameter requirements.

Current functionality represents the requirements for voice communications that all new systems must provide to gain ATC operational acceptability.

Voice capacity represents the lack of sufficient voice circuits for assignment.

Interoperability is the ability to work with current systems and compatibility with ICAO standards.

The three remaining **new functionality** criteria included the provision of new capabilities for voice, data, and integrated voice and data. Although new capabilities were highly desirable, the provision[4] of these functions was not considered as important as the first three criterion and were rated lower.

The highest level criteria and associated weights are listed in Table 3-1.

Table 3-1. Technical Model Level 1 Criteria

Level 1 Criteria	Weights	Rank
Current Functionality	58%	1
Voice Capacity	15%	2
Interoperability	10%	3
New Functionality - Voice	7%	4
New Functionality - Data	7%	5
New Functionality - Voice and Data	3%	6

3.3.2. Risk Model

The Risk model is a single-level model with eight criteria that are depicted in Table 3-2. The relative importance of the eight criteria within the Risk Model was established using a scale of 1 to 5, with five being the highest weight.

Weights of "five" for Operational Acceptability, "three" for Technical and Transition /Integration, and "one" for the remaining five risk categories were assigned. Operational Acceptability risk was weighted highest because it comprises risks associated with operator/machine interface, operational procedures, and human factors. High operational unacceptability may result in unsafe operations for airborne users.

[4] For example, new functionality for voice is improved channel access (contention/call queuing, prioritization, emergency calls, G/A override, circuit blockage override, and status display).

Table 3-2. Risk Model Level 1 Criteria

Level 1 Criteria	Weight	Rank
Operational Acceptability Risk	5	1
Technical Risk	3	2
Transition / Integration Risk	3	3
Implementation Risk	1	4
Schedule Risk	1	5
Security Risk	1	6
Supportability Risk	1	7
Cost Overrun Risk	1	8

Technical and Transition/Integration risks address the likelihood that a system might not operate as intended and be incapable of a smooth transition.

3.3.3. Overall Evaluation Model

The objective of the Overall Evaluation Model was to determine the best architectural alternative, irrespective of acquisition strategy (i.e., lease versus buy). The Overall Evaluation Model is a single-level model similar to the Risk Model. Table 3-3 depicts the six evaluation criteria.

Table 3-3. Overall Criteria and Weights

Criteria	Weight	Rank
Technical	45	1
Risk	15	2
Schedule for initial operational capability (IOC) in 2005	15	3
Transition and Integration	15	4
Cost	5	5
Supportability	5	6

The Technical criterion was weighted highest, followed by Risk, Schedule, and Transition/Integration, all weighted equally. Cost and Supportability were weighted the least.

The Technical criterion was assigned a weight of 45 out of 100 because the team assessed it as the most important aspect of the new system. The next three criteria (Risk, Schedule, and Transition/Integration) were judged to be equal in weight at 15 each. Cost and Supportability were rated equally at 5 each.

To reduce the margin of error, a low weight was allocated to criteria that had inadequate information to evaluate. For example, sufficient credible cost information was not available during the alternative evaluation. The formal cost estimate was developed after the selection of a preferred alternative (described in Section 3.4). However, the relative cost among alternatives was considered.

3.3.4. Evaluation

Overall assessment and ranking of the six alternatives (plus the baseline or current system) are contained in Table 3-4. Numerical ratings are provided for Technical and Risk, with color (shaded) coded ratings shown for Schedule, Transition/Integration, Cost and Supportability. A **Green "G"** rating indicates a high probability of compliance with a given criterion. A **Yellow "Y"** rating means that a level of uncertainty exists regarding compliance with a given criterion. A **Red "R"** rating means that there is a high probability that the factor does not comply with a given criterion.

ASIDV is the only alternative that meets all of the technical requirements, was the highest rated technical alternative, and best meets the critical need for additional voice capacity. Further, this option seemed most able to provide both voice and data services using minimal equipment. ASIDV will likely not meet the voice availability requirement of 0.99999 without undue system redundancy and complexity. The team concluded that if ASIDV is selected, it should meet the NEXCOM schedule requirement, however a non-trivial amount of spectrum re-engineering and attention to co-site problems will be required.

Alternative 8.33/SDN was rated third in both overall ranking and technical rating. The team was concerned over the critical "voice quality" requirement because of the unknown effect of "high frequency roll-off" of voice spectrum. The "transmit audio clipping" requirement for 8.33/SDN is problematic because there is no mechanism in analog AM to prevent clipping. There was considerable concern with voice channel capacity. Although the 8.33/SDN system theoretically provides three times the capacity of the existing system, achievable capacity may actually be less than twice the current system due to potential co-site interference problems. Additionally, the SDN segment of this alternative would consume some of the available VHF spectrum and thereby limit the voice channel capacity.

Based on Table 3-4, the Alternatives Analysis Team recommended the international ASIDV radio system employing TDMA technology in the VHF band as the preferred alternative.

Table 3-4. Overall Assessment of Alternatives

		Evaluation Criteria / (Weights)					
Alternatives	**Overall Rank**	**Technical (.45)**	**Risk (.15)**	**Schedule (.15)**	**Transition (.15)**	**Cost (.05)**	**Supportability (.05)**
ASIDV	**1**	**0.984**	**0.889**	**G**	**Y**	**Y**	**G**
25/SDN	**2**	**0.777**	**0.778**	**G**	**G**	**G**	**G**
8.33/SDN	**3**	**0.822**	**0.611**	**G**	**Y**	**Y**	**G**
CSIDV	**4**	**0.914**	**0.750**	**Y**	**Y**	**Y**	**G**
GEO	**5**	**0.789**	**0.361**	**R**	**Y**	**Y**	**Y**
LEO/MEO	**6**	**0.650**	**0.361**	**Y**	**Y**	**R**	**Y**
CURRENT		**0.691**	**0.972**	**G**	**G**	**G**	**G**

3.4. Acquisition Strategy

To make the overall program initiative more affordable, and to defer impact on the GA community, the IAT divided the NEXCOM program into three manageable segments outlined in Table 3-5. New multimode radios will begin replacing the current analog radios in 2002 but will operate in the 25 kHz DSB AM mode until 2005. This delay is necessary to accommodate transition lead-time required by the user community to voluntarily convert existing radio systems from analog to digital. Transition from analog to digital voice will occur first, followed by transition to data communications (Segment Two). At the end of Segment Three, NEXCOM will achieve full operational capability (FOC) for digital voice and data. The program will ultimately replace all radios currently in the NAS.

Through Segment Two, there will be minimal impact on GA since NEXCOM will be implemented in areas with little or no GA traffic. A plan for transition to digital voice and data capabilities for air space typically flown by low end GA has not been determined at this time. Future coordination between the IPT and GA will address this issue.

Table 3-5. NEXCOM Goals and Objectives

Term	Definition	IOC	FOC
Segment One	Deploy new digital radios to super high and high en route sectors. Transition to digital voice in super high and high en route sectors beginning in 2005 and completing by 2008.	2002	2008
Segment Two	Begin transition to provide Data Link Capability in super high and high en route sectors, super high and high data will be operational by 2010.	2005	2010
Segment Three	Deploys radios and transitions to voice and data capabilities. Complete transition does not happen until all airspace is converted.	2010	2015

4. NEXCOM Economic Analysis -- Segment One

The NEXCOM economic analysis focuses on FAA and user life cycle costs and benefits, net present value, and benefit cost ratio. Figures are expressed in current dollars or 1998 present value dollars whichever is appropriate for the analysis.

Economic analysis is based on "most likely" input values, though inputs for many of the cost categories have a range of values due to uncertainty. Risk assessment is a technique that captures the impact of that uncertainty. It is discussed in depth in Section 5.

When a range of values is shown, the low number is the low confidence value, which means that there is an 80 percent chance the actual value will exceed the estimated value. The high number is the high confidence value, meaning that that there is a 20 percent chance the actual value will exceed the estimated value.

4.1. Life Cycle Costs

Life-cycle costs for NEXCOM include acquisition, installation, operations and maintenance, support, and disposition of the system. NEXCOM funding also provides for the development of NAS operational standards and procedures, NAS system certification, and infrastructure sustainment activities. The cost estimate was initially done in constant 1998 dollars and inflated to Current dollars (shown in Tables 4-5 and 4-6) using approved Office of Management and Budget (OMB) inflation indices. This applies to both the FAA and user community.

4.1.1. FAA Life Cycle Costs

The NEXCOM Segment One cost estimate has two major categories: 1) implementation costs and 2) expansion and sustainment costs. Implementation costs support digital voice communication in the high and super-high en route sectors and consist of radio interface units (RIUs), linear power amplifiers (LPAs), telecommunications, and spare parts necessary to replace current radios. Expansion/sustainment costs are for radios, RIUs, RCE, LPAs, and other costs required to modernize low en route, Terminal and Flight Service A/G communications at co-located sites that support more than just the high and super-high en route sectors.

The following assumptions were made for costing purposes:

1. Life cycle costs are shown from 1998 through 2020.
2. All radios will be multimode.
3. Six radios are necessary to support one ATC A/G frequency for a sector.
4. Radios need to be replaced for 24 control facilities, which include the 21 Air Route Traffic Control Centers (ARTCCs), plus the Hawaii, Guam, and San Juan Combined Center Radar Approach Controls (CERAPs).
5. 6,360 radios need to be replaced (based on current 1998 en route frequency assignments).
6. A two-percent per year rate of growth of radio requirements is assumed (based on “most likely” estimate).

Appendix A: *NEXCOM Basis of Estimates* has more detailed assumptions underlying the cost and benefits estimates.

NEXCOM costs were developed using the cost elements defined below.

System Production - Costs for procurement of new multimode radios, as well as RIUs, Radio Control Equipment (RCE), and LPAs required to sustain the current system. Segment One, requires 7,027 multimode radios beginning in 1998 through 2009, based on a two-percent growth rate without spares. The cost estimate is based on a “most likely” unit cost of $6,000, in constant 1998 dollars.

For Segment One, a total of 2,366 RIUs and 246 RCEs are required over the same period, 1,970 LPAs are required between 2002 and 2006. Estimated unit cost is $6,000 for the RIU, $5,000 for the RCE and $10,000 for the LPA.

System Engineering - These costs are included within program management below.

Program Management - Costs are for contractor efforts to plan, execute, and manage the program. This includes planning, directing and controlling the definition, development, and production of a system. Logistics and logistics support, maintenance support, facilities, training, testing, and system activation are also included. Based on the FAA Cost Factor Study (May 1988), a factor of 12 percent for program management/systems engineering was used.

System Test and Evaluation - IPT provided costs supporting components, systems testing, and evaluating results to assess design, performance, and supportability. These costs include the design, development, and conduct of the test for the FAA Technical Center and for AOS travel and per diem.

Training costs - Costs are for contractual services, devices, accessories, aids, and equipment used to train FAA operations and maintenance personnel. Cost estimates were based on $20,000 per class of 12 students, with one class per remote communication facility.

Data - IPT provided costs for data items deliverable to the FAA. They include acquiring, writing, drafting, assembling, reproducing, packaging, and shipping of technical publications, engineering data, management data, and support data.

Operational Site Activation - Construction, conversion, utilities, and services costs for facilities to house and service the system. Table 4-1 identifies these cost elements and estimates.

Support Equipment - Costs required for supporting and maintaining the system or subsystem. The IPT provided a cost of $50,000 per set of support equipment and the assumption that they would be required at 75 percent of the remote communications facilities.

Industrial Facilities - Construction, conversion, or expansion of facilities costs for production, inventory, and contractor depot maintenance. The IPT identified no requirements for NEXCOM.

Initial Spares and Repair Parts - Initial inventory of consumables and spares, but not replenishment of that inventory. Estimate assumes a depot sparing level of five percent of the hardware.

Pre-planned Product Improvement - Costs programmed to update the system for obsolescence of parts, advanced technologies, etc. Estimated as ten percent of the total system production costs and are phased equally over three years beginning in 2012.

Table 4-1. Cost Elements Identified

Cost Element	Factor/Source
Non-recurring Telecommunications	$3,500 per RCE / per IPT
Recurring Telecommunications	$500 per RCE / per IPT
Infrastructure	5% of all hardware, depot, and spares
Ancillary Equipment	10% of all hardware, depot, and spares
F&E Manpower	IPT
F&E Travel & Per Diem	IPT
Hazardous Material Handling	IPT

Operations and Maintenance Costs - ARX-200 has the responsibility of operations and maintenance (O&M) cost estimates. ARX-200 maintains the methodology, supporting detail, and documentation of cost estimates associated with this program. Costs included are for the on-going operation and maintenance of the system, including those listed below.

Administration and Operations - Costs for the organizational infrastructure to ensure that the NAS maintenance and support functions can be performed. Specific responsibilities include staffing, National Airspace Integrated Logistics Support (NAILS) management, leased telecommunications, utilities, leases, etc.

Maintenance - Costs associated with the maintenance function. They include site level contractor maintenance, direct work maintenance staffing, commercial depot repair, regional support costs, and other site or depot maintenance costs not captured elsewhere.

Logistics Support - Provides the logistics infrastructure needed to support NAS maintenance. Specific costs are consumables, supply support, support equipment, technical data, training, direct work logistics support staffing, and facilities.

Disposition - Final cost element in system life cycle. Costs for detoxification, transportation, disposal, and long term storage of material from the product less any salvage value.

Table 4-2 illustrates the FAA F&E life cycle cost by major categories for Segment One by fiscal year (FY). Life cycle cost estimates reflect high-confidence values, meaning that there is only a 20 percent chance that the actual cost will exceed the estimated cost.

Table 4-2. A/G Communications Costs, including NEXCOM Segment One (Current $M)

	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09-20	Total
NEXCOM F&E	**14.3**	**11.6**	**36.6**	**64.9**	**88.7**	**86.8**	**78.0**	**71.2**	**63.6**	**44.0**	**26.5**	**33.2**	**619.3**
Segment One	2.2	0.5	10.1	24.2	54.6	51.9	48.3	57.7	56.0	41.5	25.2	0.0	405.5
Implementation	*2.2*	*0.5*	*10.1*	*24.2*	*46.6*	*43.8*	*40.0*	*39.5*	*37.4*	*22.5*	*5.8*	*33.2*	*305.9*
Expansion/ Sustainment	*0.0*	*0.0*	*0.0*	*0.0*	*8.0*	*8.1*	*8.3*	*18.2*	*18.6*	*19.0*	*19.4*	*0.0*	*99.6*
Legacy*	12.1	11.1	26.5	40.7	34.1	34.8	29.7	13.5	7.5	2.6	1.3	0.0	213.9
NEXCOM O&M	95.1	98.6	100.8	105.3	106.6	110.2	113.6	118.9	126.5	131.2	135.7	1810.1	3052.6
Segment One					106.6	110.2	113.6	118.9	126.5	131.2	135.7	1810.1	2652.8
Sustainment #	95.1	98.6	100.8	105.3									399.8
Total	109.5	110.2	137.4	170.2	195.3	197.0	191.6	190.1	190.1	175.2	162.2	1843.3	3672.1

*/ Legacy = Current AND-340 programs; #/ Sustainment = O&M to support Legacy Sustainment

4.1.2. User Life Cycle Cost

User life cycle costs shown in Tables 4-4 through 4-7 include costs for avionics, installation, upgrades, spares, certification, re-certification and down time. All costs were calculated based on the following assumptions:

- Life cycle of avionics is 15 years.
- Military aircraft will replace current analog VHF radios with VHF digital radios and will not replace UHF radios.
- For data link applications, digitally capable aircraft can use current cockpit display units with software upgrades to current communications management units (CMUs).
- Non-digitally capable aircraft will require new cockpit display units and new CMUs for data link applications.
- User community will receive at least five years lead-time to equip. Air carriers are not expected to incur additional out-of-service time beyond regular maintenance cycles.
- GA aircraft that are not currently radio equipped will not equip with VHF digital radios.
- Beginning in the year 2003, new aircraft will come equipped with VHF digital radios and the cost for such equipage is not included in this analysis.

Upgrades will be announced via service bulletins and will include enhancements in annunciation, human factors, and operational characteristics.

User equipage rates used are listed in Table 4-3.

Table 4-3. User Equipage Rates

	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Air Carrier	15%	30%	45%	60%	75%	90%	95%	100%	100%	100%	100%	100%	100%
Regional/Commuter	15%	30%	45%	60%	75%	90%	95%	100%	100%	100%	100%	100%	100%
Corporate GA	15%	30%	45%	60%	75%	90%	95%	100%	100%	100%	100%	100%	100%
Radio Equipped GA	5%	10%	15%	20%	25%	30%	40%	50%	60%	70%	80%	90%	100%
Overall GA	5%	10%	16%	21%	26%	31%	40%	50%	58%	67%	76%	85%	94%
Military (VHF Equipped)	15%	30%	45%	60%	75%	90%	95%	100%	100%	100%	100%	100%	100%

Table 4-4 shows additional user equipage assumptions made for this analysis. The table depicts the following assumptions.

- Total GA equipage and percentage of that number that are corporate and other GA.
- Percentage of regional /commuter aircraft that are assumed to use high en route airspace with 50% having digital avionics and 50% having non-digital avionics.
- Air carriers equip with 50% having digital avionics and 50% having non-digital avionics.

Table 4-4. User Equipage Assumptions

User	% of Category
General Aviation assumptions	
Overall equipage percent	94
Corporate percent of total GA	5
All other GA	89
Percent of regional/commuter that use high en route airspace	50
Percent of regional/commuter avionics type (digital/non-digital)	50/50
Air Carrier overall equipage assumption	100
Percent of air carrier aircraft avionics type (digital/non-digital)	50/50

Table 4-5 depicts the avionics cost estimates used for all segments. These estimates have a wide variance because standards have not been identified. Some estimates, such as the cockpit display unit (CDU) installation, varies between the air carrier and commuter because of the relative cost of the aircraft being out of service.

Table 4-5. NEXCOM Avionics Costs for all Segments ($1998)

	Air Carriers		Regional / Commuter		Low-end	Military
Cost Component	Digital	Non-Digital	Digital	Non-Digital	GA	
VHF Digital Radio(s)	$75,600	$75,600	$25,600	$25,600	$5,000	$48,000
Digital Radio Wiring	3,600	1,440	2,400	960	1,040	1,800
Installation	780	6,240	780	2,600	0	6,000
CMU Software Upgrade	3,200	0	3,200	0	0	0
CMUs	0	51,200	0	51,200	0	0
CMU Installation	0	6,500	0	1,040	0	0
Cockpit Display Unit	0	11,600	0	11,600	0	0
CDU Installation	0	2,600	0	1,300	0	0
Total Cost	83,180	155,180	31,980	94,300	6,040	55,800

Table 4-6 contains the total user life cycle costs.

Table 4-6. User Life Cycle Costs (Current $M)

	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11-20	Total
Air Carrier	0.0	0.0	0.0	0.0	0.0	165	169	172	176	118	37	38	39	436	1352
Total User	0.0	0.0	0.0	0.0	0.0	407	416	425	434	332	194	198	203	1015	3624

4.2. Benefits

NEXCOM will provide increased spectrum capacity, reduce circuit blockage, reduce risk associated from unauthorized access, increase security and, in the long term, reduce maintenance costs. It will provide ATC the capability to accommodate the growing number of sectors and services, as well as “free flight” by increasing the number of circuits available within the current VHF ATC spectrum. Additionally, NEXCOM provides a data link communications capability to all classes of users.

4.2.1. FAA Benefits

The FAA will benefit in the long term from avoided costs of maintaining the analog system, because NEXCOM equipment replaces a major portion of the existing A/G communications radio systems. However, the avoided costs of maintenance will not begin to accrue until after Segment One. In addition, NEXCOM can support voice and data communications within a single avionics system.

FAA analog radio acquisition costs required to support growth in frequency assignments outside the high/super high en route sectors will be reduced because analog circuits will be “freed up” as NEXCOM is deployed. As current analog radios are replaced with new digital radios, a small percentage of analog radios will be salvaged to replenish the analog radio maintenance inventory.

For Segment One, FAA benefits of avoided maintenance and acquisition costs were noted but not used in the economic analysis, because these cost savings were not significant when compared to user benefits.

4.2.2. User Benefits

NEXCOM can benefit users by:

- Providing circuits for additional operator positions to support new runways, thereby reducing ground and airborne delays in the terminal area;
- Making additional frequencies in the en route environment available for implementing new sectors leading to reduced delays;
- Providing additional air traffic services such an AWOS and ASOS due to the availability of additional frequencies.

Construction of additional runways can reduce delays. An evaluation of runways projected for construction, prior to 2006, indicated that frequencies would not be available for additional positions needed for 16 of the 21 runways. It has become increasingly difficult for the FAA to assign frequencies in several heavily populated areas of the country, such as Atlanta and Chicago, due to electronic interference. By providing more circuits per frequency in the en route airspace, new frequencies are made available for use in the terminal environment.

Four airports were analyzed to determine the user delay costs that would be incurred if a planned new runway could not be opened or used. Details of this analysis are contained in a separate IAT report entitled, *Preliminary Report 7: Terminal-Area Impacts of VHF Voice Radio Frequency Unavailability*. Delay costs were projected through FY20 and determined to be approximately $13.9B, of which only a small portion (ten percent) could be attributed to the NEXCOM program for providing the needed frequencies. The portion of avoided delay-costs attributed to NEXCOM was approximately $1.4B. Other factors such as land availability, navigation equipment, radar, automation, etc. account for the majority of the benefits.

Miami, St. Louis, Detroit, Phoenix, Midway, and Orlando are among the 16 airports projected to have a frequency allocation deficiency but were not evaluated due to lack of data. These airports are projected to exceed 20,000 annual hours of delay by CY06 without capacity improvements. Therefore, $1.4B in user benefits (from the four airports) for reducing terminal-area delays is conservative. (It should be noted that the joint FAA/user/industry NEXCOM working group thought that these benefits were low but did not have the time or data to quantify and substantiate greater benefits).

Delays that occur in the en route airspace due to increasing air traffic can sometimes can be reduced through resectorization, i.e. splitting a sector in two, so that two controllers can manage the airspace, thereby reducing each controller's workload. Splitting a sector requires the availability of additional frequencies enabling new positions to communicate with aircraft. An analysis of sectors projected to be candidates for resectorization between the CY98 and CY15 is included in a separate IAT report entitled, *Preliminary Report 9: NEXCOM's Impacts on En-Route Airspace*.

The team found that frequencies are unavailable for 52 of the 204 sectors projected as candidates for resectorization. Analysis of the en route delays determined that the user benefit in avoided delay costs would be approximately $36M. The benefits of these avoided costs are all attributable to NEXCOM because controllers and additional equipment are available or will be available to support resectorization.

Table 4-7 illustrates the NEXCOM user benefits.

Table 4-7. Most Likely NEXCOM User Benefits (Current $M)

Benefit Driver	Benefit Metric	Economic Benefit
Reduced ground and airborne delays	Runways implemented at major airports that have severe traffic congestion (i.e., Atlanta, Cleveland, Minneapolis, and Charlotte)	$1,422 M
Reduced delays in the en route environment	New sectors can be implemented.	$36 M
Total User Economic Benefit		**$ 1,458M**

The NEXCOM user benefits by year are contained in Table 4-8.

Table 4-8. NEXCOM User Life Cycle Benefits

Year	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	Current $M
Terminal Capacity	0	0	55	59	64	68	73	77	82	
En Route Capacity	0	0	0	1	1	2	2	3	3	
Subtotal	0	0	55	60	65	70	75	80	85	
Year	**FY12**	**FY13**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**FY19**	**FY20**	**Total**
Terminal Capacity	86	91	95	99	105	110	115	119	124	**$1,422**
En Route Capacity	2	2	2	2	3	3	3	3	4	**$36**
Total Value	88	93	97	101	108	113	118	122	128	**$1,458**

4.2.2.1. Safety Benefits

One of the goals of NEXCOM is to reduce the potential for accidents and incidents specifically due to stuck microphones, simultaneous broadcasts, and radio frequency interference (RFI). Incidents include OEs, NMACS, and PDs.

Databases from the FAA's National Aviation Safety Data Analysis Center (NASDAC), National Aeronautics and Space Administration (NASA) Data Systems, and the National Transportation Safety Board (NTSB) were searched for accidents and incidents potentially caused by communications problems. The searches included the time period January 1980 to July 1996.

Databases searched included the following:

- NTSB Aviation Accident and Incident Data System
- Aviation Safety Reporting System (ASRS)
- Accident/Incident Data System (AIDS)
- Pilot Deviation System (PDS)
- Operational Errors/Deviation System (OEDS)
- Near Midair Collision System (NMACS)

These databases were searched for incidents involving stuck microphones, simultaneous broadcasts, RFI, or frequency congestion.

Not all NEXCOM alternatives will resolve these problems. Each incident was evaluated, based on whether implementation of any of the NEXCOM alternatives that have been proposed so far might have resolved or prevented the problem. Each case was rated "2" (yes), "1" (maybe), or "0" (no), depending on the degree to which the problem may be resolved or prevented.

The results of the NASDAC and ASRS data base analysis are shown in Table 4-9 and Table 4-10, respectively. The total percent of incidents evaluated (for each problem) that could have been prevented by a TDMA-based solution are shown at the bottom of these tables.

Table 4-9. FAA Data Systems Evaluation

	Stuck Mike	Simulated Broadcast	Radio Frequency Interference	Frequency Congestion
Number Rated "0" (No)	0	0	6	10
Number Rated "1" (Maybe)	3	1	3	19
Number Rated "2" (Yes)	21	1	3	27
Total Number of Reports	24	2	12	56
% of Total Rated "2" (Yes)	88%	50%	25%	48%

Table 4-10. Aviation Safety Reporting System Evaluation

	Stuck Mike	Simulated Broadcast	Radio Frequency Interference*	Frequency Congestion
Number Rated "0" (No)	8	66	5	244
Number Rated "1" (Maybe)	12	31	18	81
Number Rated "2" (Yes)	156	98	21	123
Total Number of Reports	176	195	44	448
% of Total Rated "2" (Yes)	89%	50%	48%	27%

*/ As discussed in Section 5.1.5, there is a risk that TDMA radios will not reduce or resolve the RFI.

An attempt was made, to evaluate Unsatisfactory Condition Reports (UCRs) that were made available to the IAT (the UCR provides agency employees a direct and simple means of advising management of unsatisfactory conditions).

The same methodology, described above, was used for evaluating incidents obtained from the UCRs. A total of 173 UCRs were reviewed, of which 101 were rated "2" (i.e., Yes, a TDMA alternative would have prevented the UCR). Another 13 were rated "1" (i.e., Maybe a UCR would have been prevented), and 59 were rated "0" (i.e., No, the UCR would not have been prevented) or Not Applicable. Analysis indicates that 58% (101 of 173) of the UCRs evaluated could have been prevented by a TDMA alternative.

The IAT made the following conclusions based on the above safety analysis:

- Safety incidents since 1983 have been at low rates relative to the total number of annual operations.
- Although no accidents have occurred that were directly caused by or attributed to an A/G communications problem, the implementation of TDMA in A/G radios should reduce the rate of operational errors and deviations due to A/G communications.
- Safety benefits that are derived solely from reducing the rate of incidents are not easily quantified in terms of costs avoided.

In summary, the safety analysis indicated that improved A/G communications provided by a TDMA-based A/G radio could reduce the rate of operational incidents. Safety benefits, which are derived solely from reducing the rate of incidents, cannot be quantified in terms of costs avoided because there is insufficient data to quantitatively link improved communications with reduced accidents.

4.2.2.2. Voice Security Benefits

One objective of NEXCOM is to reduce the threat to safety caused by radio transmissions of unauthorized users. This occurs when non-ATC personnel or non-airspace users intentionally transmit on assigned ATC communications frequencies.

Spectrum Policy and Management (ASR-1) maintains records of unauthorized user transmissions or events, and has identified 127 unauthorized transmissions/events. The 127 events were analyzed to determine if any events could have been prevented or minimized by NEXCOM. Analysis indicated that unauthorized transmissions could not have been prevented, but in 122 of the 127 events the risk of a successful intrusion could have been minimized through implementation of a TDMA-based alternative. These benefits were not quantified due to insufficient data linking unauthorized transmissions to accidents.

4.2.3. Value of Spectrum

Spectrum has economic value. Private industry buys spectrum through submitting bids at Federal Communications Commission (FCC) auctions. Based on bids for spectrum similar to FAA's spectrum, an economic value was estimated for the FAA's spectrum shortfall. The monetary value of spectrum projected to be needed by the FAA between 1998 – 2020, could range from $101M to $812M with a most likely economic value of $405M.

However, for the FAA, spectrum represents an opportunity cost, rather than an economic value. Spectrum has economic value only if it can be converted to money directly by the FAA. For this reason and to be consistent with the team's conservative approach to calculating benefits, the value for spectrum was not included in the calculation of NEXCOM benefits.

4.2.4. Data Link

Data link capabilities can be provided through an integrated voice and data system. Data link benefits were not quantified, however, the IAT noted that previous FAA and C/AFT (communications, navigation, and surveillance--CNS air traffic management--ATM Focus Team) studies project that increased use of data link in the cockpit will increase pilot effectiveness resulting in reduced costs for air carriers. By receiving more current information, pilots can make informed decisions required to mitigate or avoid effects of swiftly changing weather patterns and unexpected circumstances. Studies further project that benefits will accrue from providing GA with a data link capability that will enable the GA community to display graphical weather inside the cockpit. Data link is not scheduled for implementation in NEXCOM until Segment Two, FY05-FY10.

Previous studies[4] indicate the FAA may benefit from increased controller productivity through data link applications.

4.3. Net Present Value

Net present value (NPV) is the difference between the present value (PV) of benefits minus the PV of incremental costs. Incremental costs are the additional costs incurred, above a "status quo" baseline, to implement a program which result in "benefits". If the results are positive, then the benefits are greater than the costs, and a project is economically beneficial. Using the 80 percent

[4] *User Benefits of Two-way Data Link Delay and Flight Efficiency;* Bibliography 14

confidence values for the incremental costs and 20 percent confidence value for the benefits, the NPV ranges between ($28M) and $264M. The most likely level is $115M. Benefit/Cost Ratio

The benefit/cost (B/C) ratio is calculated by dividing the PV of benefits by the PV of the incremental costs. The B/C ratio is used to determine the relative economic merit of the candidate solution. If the ratio is greater than one, then the benefits are greater than the costs, and the project is economically justifiable. Using the 80 percent confidence values for the incremental costs and the benefits, the NEXCOM B/C ratio ranges between 0.9 and 1.7. This range is based on the assumption that there are some variables that could change or vary the final outcome but still provide a favorable benefit to cost ratio. The most likely level provides a B/C ratio of 1.3, and represents a conservative assessment. Table 4-11 summarizes how the B/C ratio for NEXCOM Segment One was determined.

4.4. Economic Summary

Table 4-11 is a summary of how NEXCOM Segment One NPV and B/C ratios were determined.

Total life cycle costs used in the economic analysis consist of FAA F&E and OPS costs and air carrier avionics costs. For analytic consistency, air carrier avionics costs were used instead of total avionics costs because user benefits for Segment One are attributable primarily to the air carriers. Economic analyses for Segments Two and Three must consider the costs and benefits attributable to other user communities. Ranges and most likely values for costs in current dollars correlate to the costs in Tables 4-2 and 4-6, which display the 80% confidence values. Total life cycle costs were then calculated in constant 1998 dollars and are shown in Table 4-12.

Incremental costs were determined by calculating the difference between the costs of maintaining the current analog system (the reference case) and the total costs of Segment One. Ranges for incremental costs are shown in constant 1998 dollars.

The present value of incremental costs and benefits was calculated by applying a seven-percent discount rate to the total life cycle incremental costs and benefits in constant 1998 dollars.

Table 4-11. Range of Estimates at the 20/80% and 80/20% Confidence Level ($M)

NEXCOM COSTS	Range	Most Likely*
FAA F&E (Current $)	610 - 619	618
FAA OPS (Current $)	3032 - 3053	3042
User Avionics (Current $)	1190 - 1352	1281
Total Costs (Current $)	4,692 - 5,160*	4,941
Total Costs (Constant $1998)	3,735 - 4,098	3,927
PV Total Costs	2,041 - 2,213	2,136
PV Incremental Costs	361 - 452	415
NEXCOM BENEFITS	**Range**	**Most Likely***
Benefits (Current $)	1,458 - 2573	2,049
Benefits (Constant $1998)	1,052 - 1,830	1,457
PV Benefits	383 - 666	530
NPV	(28) - 264	115
B/C Ratio	0.9 - 1.7	1.3

*/ 20/80 and 80/20 confidence totals are based on Monte Carlo simulation and therefore are not additive.

5. Risk Assessment

The investment analysis Transition Team performed programmatic risk assessments to identify "watch items" for the NEXCOM program office and to evaluate risk mitigation measures. The Economic Analysis Team performed risk analysis and assessment to capture the uncertainty of costs and benefits.

User commitment is the primary programmatic risk. There was concern that some air carriers would resist equipping aircraft with digital radios in the 2004+ timeframe after completing a significant capital investment to equip some of their aircraft with 8.33 analog/VDL-2 radios for operation in some European countries in the preceding five years. To mitigate this risk, the FAA requested user and industry representation on a special NEXCOM work group. The following companies/organizations were represented on the joint FAA, user, industry work group: American Airlines, Delta Airlines, United Airlines, U.S. Airways, ATA, AOPA, and Northwest Airlines. Rockwell-Collins was consulted for radio cost data. Beginning with the initial workgroup meeting on March 4th, 1998, the user community was actively involved in the NEXCOM investment analysis. The FAA briefed users on the alternatives analysis and transition analysis on April 1st, 1998. Following the presentation, the users requested a briefing on user costs and benefits as soon as the economic analysis was complete. On April 24th, the FAA presented results of the economic analysis. At that meeting, the air carriers commented that cost estimates appeared reasonable but benefit estimates were very conservative. Since many of the safety and security benefit issues raised by the users are hard to quantify and substantiate, the IAT agreed to emphasize the qualitative nature of these benefits in its briefing to the JRC. As a result of this dialogue with the IAT, users and industry support Segment One of the NEXCOM program.

Risks associated with the uncertainty of costs and benefits were evaluated using two software packages, *At Risk*™ and *Crystal Ball*™. Both are risk analysis models based on Monte Carlo simulation. The models developed outputs that had a range of values, each value representing a particular confidence level, depending on the simulation run.

Table 5-1 summarizes the different risk assessments.

Table 5-1. Risk Factor Assessment

NEXCOM	Risk Level	Mitigation	Risk Drivers
Technical/ Operational	Medium	Coordination w/users and testing	Spectrum re-engineering, Transition/ Integration of digital technology, RFI
Cost F&E O&M	 Medium to Low Medium to Low	Used 80/20 estimates for both	TDMA Radio Standards have not yet been validated. Radio cost used were "best guess" from industry.
Schedule	Medium	Incremental Installation Program to identify transition issues that can be resolved early	Cost (Maintenance, Technician Support), Delay in Benefits
Benefits	Medium	Used 80/20 estimates	Delay in Benefits until cut over to Digital Voice (2005)

5.1. Technical / Operational Risk

Technical and operational risks relate to changing requirements and programmatic interdependencies, and failure to achieve technical and performance objectives. Performance objectives include capacity, reliability, availability, security, and redundancy.

TDMA is evaluated as having a medium risk of not meeting performance objectives. TDMA meets the voice capacity requirement and can meet the schedule requirement, but there will be a considerable amount of spectrum re-engineering required. The medium assessment reflects a concern that TDMA might not reduce or resolve RFI problems or have the bandwidth to accommodate all future data link requirements.

Several technical and operational risk areas and the actions that would be needed to mitigate risks were identified. These are delineated in detail in the *NEXCOM Transition Team Report*, and described in the following sections.

5.1.1. Consistency with the NAS Architecture

Close Coordination must be maintained with NAS Architecture Development Team to ensure that the NAS Architecture Plan represents the most current information available from the NEXCOM Product Team. Conversely, the NEXCOM Product Team will maintain currency on the NAS Architecture effort to ensure consistency between efforts.

5.1.2. User Equipage Operational Risk

The NEXCOM program office must keep users and avionics manufacturers involved in future operational issues with user equipage. A successful transition to VDL Mode-3 can occur if enough users install NEXCOM compatible radios. Individual Sectors will transition to Digital Voice capability from Analog voice as users agree to equip to fly within the identified sectors.

The FAA hosted three NEXCOM joint FAA-user meetings at which consensus was achieved regarding the impact of VHF spectrum congestion on the user community. The IAT stressed that a collective (user community and FAA) agreement on technical, operational, and economic issues and a commitment from users to reequip was required in order for the NEXCOM program to succeed. The Product Team will periodically brief the User Community on its plans and progress. It will continue the important dialogue begun during the IA process to ensure that any issue with user transition to VDL-3 equipage is identified and addressed early to ensure long-term success.

5.1.3. NEXCOM Test & Evaluation

The NEXCOM Product Team is developing an operational, test, and evaluation (OT&E) strategy for all major test efforts to mitigate risk. These efforts include continuous requirements revalidation, sub-system performance evaluation, functional systems testing, specification validation, and operational testing. To implement the OT&E strategy, the William J. Hughes Technical Center (WJHTC) will establish a test bed that will simulate test environments and conduct OT&E.

The NEXCOM OT&E strategy also allows for NAS upgrades to new services by utilizing a segmented approach. Each segment allows for planning and testing of new upgrades prior to full integration. This segmented approach ensures that NEXCOM components are capable of the following:

- Operating in analog modes with existing NAS equipment, and;
- Providing a smooth transition.

5.1.4. Security Risk

The risk that NEXCOM would not achieve the required degree of security was rated as “low”. The digital technology of TDMA provides features that can make it difficult for unauthorized users to transmit surreptitiously on the circuit to disrupt services. An ID (identity) bit can be programmed to activate an indicator in the cockpit so that the pilot knows whether a transmission is legitimate or bogus. Security is not a major discriminator because most candidate architectures are inherently more secure than the current system in terms of signal waveform robustness and access. However, The Product Team will conduct a Security Feasibility Assessment as part of the specification development process.

5.1.5. Radio Frequency Interference

Unintentional interference from other electronic equipment is a risk to safety. Whenever frequencies are affected, communications can go unheard or be misinterpreted by airspace users. Miscommunications pose a potential safety hazard to aircraft in flight. Miscommunications due to frequency interference can cause pilot deviations or operational errors leading to near misses and accidents. There is a risk that the NEXCOM TDMA radios will not reduce or resolve the RFI problem. However, actions are ongoing to redefine the radio RF mask in the standards and identify other means of RFI reduction.

5.2. Cost Risk

Deployment of multimode radios at high/superhigh en route facilities operating in analog mode, requires a major expenditure of F&E dollars to procure and install the radios and supporting hardware. This includes multimode digital radios, RIUs with an integrated voice encoder (VOCODER), RCE, digital radio maintenance support equipment, and telephone company equipment (TELCO).

Specific expenditures must be closely monitored to ensure cost and schedule impacts are kept to a minimum. The costs include:

- Plant engineering - environmental, structural and electro-mechanical engineering required to support infrastructure upgrades.
- Electronics Engineering - equipment wiring within equipment racks, installation of new racks and transition antenna cabling.
- Plant construction - infrastructure upgrades required by engineering project plans.
- Electronic installation - physical installation, interconnection and system checkout.
- Operations resources - non-F&E resources utilized to implement NEXCOM.
- Maintenance technicians - new equipment certification and coordination of outages to ensure work plan and schedule are maintained.

The length of the time that both analog and digital radios must be maintained is a major risk factor on O&M costs. However, the risk that program replacement radios will be needed at a faster rate than expected or that equipment costs will increase faster than expected is viewed as a medium to low risk. It will be mitigated through continuous monitoring of failure rates and equipment cost growth.

NEXCOM O&M costs include a variety of functions and categories. They include, program management, hazardous material (HAZMAT), maintenance, and facility's transition and management. Based on Sponsor, AF and product team experience with similar equipment, there is a medium to low risk that these costs will exceed the cost estimate. Again, it will be mitigated through continuous monitoring of cost growth.

As new, high priority requirements are identified, existing requirements of lower priority will have to be identified and evaluated as offsets if the new requirements are to be satisfied. Increasing requirements should not be allowed to cause erosion of cost risk margins, or the margin between the high confidence (80/20%) and "most likely" cost estimates.

5.3. Schedule Risk

Schedule risk identifies the inability to implement a system by the planned dates. A schedule slippage or delay adversely affects both costs and benefits. As the transition from analog to digital radio communications evolves, the FAA must support full maintenance operations for both. This requirement exists until transition begins in CY05. At that time, the FAA can reduce maintenance support for analog radios to a level capable of supporting the remaining analog radios in use in the NAS.

Any delay or slip in the schedule will also result in the delay of benefits. Benefits are currently projected to begin once the A/G communications system has cut over to operate in the digital voice mode. The analog to digital cut over is scheduled to begin in 2005.

A medium risk exists with the NEXCOM program schedule, primarily driven by transition/integration issues. The following issues impact schedule risk:

5.3.1. Transition/Integration

Several factors can affect transition to digital radios, including the following:

- Air Traffic concerns - Air Traffic could raise concerns and issues during installation that may require additional time to resolve.
- Training - Additional training for controllers and technicians may be required.
- F&E Staffing - Five work crews per region for six years are required to complete installation of the NEXCOM Segment One radios. The FAA may reduce funding below the amount required to sustain this work effort.
- User Equipage - Slower than projected user equipage could delay NEXCOM. Section 5.1.2 provides additional detail.
- Infrastructure Support - NEXCOM is based on infrastructure support continuing at current planned levels. Future cuts in infrastructure support funding could delay NEXCOM.
- Legacy Program Funding - NEXCOM transition planning was predicated on prior completion of current legacy programs, such as the Backup Emergency Communication replacement

program. Reduced funding for legacy programs below currently planned levels would delay the NEXCOM schedule.

NEXCOM Transition Team plans to mitigate schedule risk by developing an incremental installation program that can identify issues early and continually track issue resolution plans to ensure success.

5.3.2. Standards and Procedures Validation/Certification

By planning ahead, rulemaking within the Standards and Procedures Validation and Certification process will have a negligible impact on schedule. New rules are required to restrict aircraft from flying 24,000 and above if not equipped with digital radios. Implementation of this rule may take up to two years. Work efforts in this area will begin shortly and will be tracked by the Product Team.

5.3.3. User Equipage Schedule Risk

Avionics equipage risk is the probability and consequences of users failing to equip with the required radios at the assumed equipage rates and schedules. Equipage risk is impacted by the resistance of the user community to change from analog to digital radios and/or unavailability of digital radios. New digital radios require a significant capital investment. This is the basis of the resistance from the user community, particularly GA. Strong support for NEXCOM from the air carriers reduces this risk.

The economic analysis used conservative estimates for air carrier equipage rates. Achievement of key FAA programmatic milestones is largely dependent on user equipage strategy. As the FAA achieves NEXCOM program milestones, air carriers can develop and modify their equipage transition plans. This approach allows the air carriers to accomplish transition during regular maintenance cycles and avoid unnecessary or unscheduled down time. There is a strong probability that air carriers will meet or exceed the assumed equipage rates because the air carriers accrue the majority of the benefits. Table 4-4 showed the assumed equipage rates.

To mitigate this risk and encourage user equipage, the Product Team will periodically brief the User Community on its plans and progress. It will continue the important dialogue begun during the IA process to ensure that any issue with user transition to VDL-3 equipage is identified and addressed early to ensure long-term success

Segment 1 does not immediately affect GA, which will transition to NEXCOM VDL-3 compatible radios during Segment Three.

5.4. Benefits Risk

The benefits risk assesses the likelihood that the candidate solution fails to achieve the level of benefits anticipated in its design. The following sections show the risk analysis and assessment of the benefits for NEXCOM.

5.4.1. Avoided User Delays

The majority of benefits for NEXCOM are realized by reducing or avoiding future user delays, both in the terminal and en route areas. The economic analysis calculated en route delay benefits using the NASPAC (NAS-wide, Macro Simulation Model) model to predict where future traffic congestion would occur. The economic analysis was based on terminal benefits that were derived from existing studies. These benefit studies used the Airport and Airspace Simulation Model (SIMMOD), Airport Delay Simulation Model (ADSIM), and Runway Delay Simulation Model (RDSIM). Models are gross representations of reality, and cannot capture all factors and relationships. Therefore, model projections have some degree of inaccuracy. NEXCOM economic analysis calculated benefits using established methodology and current data to minimize the risks of overstating benefits.

User equipage is a major driver for both delay benefits and user avionics costs. The user community has indicated the need to equip with digital radios. However, the equipage rate for each class of user is different based upon the segmented approach to implementing the NEXCOM Program and the perceived benefits to that user. Specific conversion rates were estimated for the user avionics cost analysis. A slow user avionics equipage rate delays benefits. An airline equipage rate delay in turn delays the implementation of digital voice communications in the en route airspace. Additional frequencies will not be available for the terminal areas until a sufficient amount of the en route airspace converts to VDL-3 communications.

As mentioned previously, continuing dialogue with the user community is key to encouraging equipage and thereby realize the identified benefits.

5.4.2. Resectorization

The risk with resectorization benefits is that prior to FAA resectorization of airspace there must be a need to resectorize and create new sectors. Workarounds and administrative maneuvers may reduce or lower the impact of congestion in specific sectors. Benefits will accrue, however, regardless of how the improved sector flow is brought about, whether it is by resectorization or by procedural actions.

6. Affordability Assessment

The IAT briefed the NEXCOM APB to the SEOAT on May 1, 1998. The SEOAT determined the NEXCOM program (Segment One only) was affordable under the current agency budget baseline. Table 6-1 depicts the funding profiles associated with the NEXCOM program as compared to the NAS Architecture proposal developed to meet the Office of Management and Budget funding targets for 2000 to 2004.

Table 6-1. NEXCOM F&E Funding Profiles (Current $M)

	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05-20	Total
Architecture	2.2	0.5	9.7	76.6	85.2	89.4	116.3	596.3	976.2
IA Profile	2.2	0.5	10.1	24.2	54.6	52.0	48.3	213.6	405.5

The SEOAT was briefed on the out year O&M increases due to NEXCOM and Legacy systems being maintained concurrently. They were told radio maintenance costs would probably go down when the radios began being remotely monitored by the NIMS.

As a result of this meeting the NAS Architecture profile was adjusted to reflect the investment analysis profile.

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7. Next Steps

There are significant risk areas and areas of uncertainty in the estimates. To increase confidence in the estimates and to help the FAA better manage risks, the IAT proposes the following steps:

- Complete Standards work for VDL Mode 3 (TDMA).
- Complete Vocoder testing in support of VDL Mode 3.
- Investigate/Negotiate potential role in Flight 2000 Program.
- Develop Risk Mitigation plan.
- Work closely with DoD JTR Initiative, develop options for continuing support of UHF operations.
- Develop/Manage Human Factors Plan.
- Establish prototype testbed at FAATC for vendor participation.
- Develop spectrum transition plan.
- Establish prototype testbed at FAATC for vendor participation.
- Complete functional specification in partnership with industry.
- Develop SIR package with industry.

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8. Recommendations

Based on information provided in the NEXCOM IAR the IAT made the following recommendations to the JRC:

- Reaffirm the need for the NEXCOM program initiative.
- Affirm the recommendation for TDMA VDL Mode 3 as the preferred alternative for NEXCOM Segment One.
- Affirm the segmentation approach to the NEXCOM program.
- Approve the Investment Decision for NEXCOM Segment One.
- Approve the proposed APB (*Acquisition Program Baseline Next Generation Air/Ground Communications System (NEXCOM), Preferred Alternative Segment One*).
- Assign the NEXCOM program to the Communications IPT for implementation.

⇒ The Communications IPT will provide a NEXCOM representative to DoD and have their representative participate on NEXCOM with the Communications IPT.

⇒ The Communications IPT will work with DoD to finalize a Memorandum of Understanding and/or Memorandum of Agreement.

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Glossary

Abbreviation, Acronym, Term	Definition	Initial Page
ADSIM	Airport Delay Simulation	32
AF	Airway Facilities	7
AFSS	Automated Flight Service Station	6
AHP	Analytic Hierarchy Process	10
AIDS	Accident / Incident Data Systems	22
AM	Amplitude Modulation	13
APB	Acquisition Program Baseline	1
ARTCC	Air Route Traffic Control Center	15
ASIDV	Aviation Standard Integrated Data & Voice	9
ASOS	Automated Surface Observing System	5
ASR	Spectrum, Policy and Management Office/FAA	6
ASRS	Aviation Safety Reporting System	22
AT	Air Traffic	5
ATC	Air Traffic Control	1
ATIS	Automated Terminal Information System	6
ATM	air traffic management	24
AWOS	Automated Weather Observation System	5
A/G	air/ground	1
B/C ratio[1]	benefit/cost ratio	25
CDMA	Code Division Multiple Access	9
CDU	Communications Display Unit	19
CERAP	Combined Center Radar Approach Control	15
CMU	Communications Management Unit	18
CNS	communications, navigation, and surveillance	24
CSIDV	commercial standard integrated data and voice	9
CSMA	Carrier Sense Multiple Access	9
C/ATF	CNS/ATF Focus Team	24
DoD	Department of Defense	7
DOCCON	SETA document control	2
DSB	Double Sideband	9

[1] Special characters follow alphabetic and numeric characters in sequence

Glossary

Abbreviation, Acronym, Term	Definition	Initial Page
EC	Expert Choice	10
FAA	Federal Aviation Administration	1
FCC	Federal Communications Commission	24
FAR	Federal Aviation Regulation	6
FOC	Full Operational Capability	14
FRM	Functional Requirements Matrix	10
FY	fiscal year	17
GA	General Aviation	2
GEO	Geosynchronous Earth Orbit	10
GSM	Global System for Mobile Communications	10
HAZMAT	Hazardous Material	30
IAR	Investment Analysis Report	1
IAT	Investment Analysis Team	1
ICAO	International Civil Aviation Organization	7
ID	identity	29
IFR	Instrument Flight Rules	7
IOC	Initial Operating Capability (Table 3-3)	12
IPT	Integrated Product Team	2
IS-95	Interim Standard 1995	9
JRC	Joint Resource Council	1
kHz	Kilohertz	1
LAAS	Local Area Augmentation System	5
LEO	Low Earth Orbit	10
LPA	Linear Power Amplifier	15
MEO	Medium Earth Orbit	10
MHz	Megahertz	1
MNS	Mission Need Statement	5
MSS	Mobile Satellite Service	10
NAILS	National Airspace Integrated Logistics Support	17
NAS	National Airspace System	1
NASA	National Aeronautics and Space Administration	22
NASDAC	National Aviation Safety Data Analysis Center	22

Glossary

Abbreviation, Acronym, Term	Definition	Initial Page
NASPAC	NAS-wide, Macro Simulation Model	31
NEXCOM	Next-Generation Air/Ground Radio Communication System	1
NIMS	NAS Infrastructure Management System	7
NMAC	Near Midair Collision	6
NMACS	Near Midair Collision System	22
NPV	Net Present Value	24
NTSB	National Transportation Safety Board	22
OE	Operational Error	6
OEDS	Operational Error / Deviation System	22
OMB	Office of Management and Budget	15
OT&E	operational, test, and evaluation	28
O&M	Operations & Maintenance	17
PD	Pilot Deviation	6
PDS	Pilot Deviation System	2
PRM	Precision Runway Monitor	5
PV	Present Value	24
RCE	Radio Control Equipment	16
RD	Requirements Document	9
RDSIM	Runway Delay Simulation Model	32
RF	radio frequency	5
RFI	radio frequency interference	22
RIU	Radio Interface Unit	15
SDN	Separate Data-only Network	9
SEOAT	System Engineering Operational Analysis Team	1
SIMMOD	Airport and Airspace Simulation Model	32
TDMA	Time Division Multiple Access	2
TELCO	telephone company equipment	29
TSARC	Transportation Systems Acquisition Review Council	1
TT&C	Telemetry, Tracking & Command	10
UCR	Unsatisfactory Condition Report	23
UHF	Ultra High Frequency	5
VFR	Visual Flight Rules	6

Glossary

Abbreviation, Acronym, Term	Definition	Initial Page
VHF	Very High Frequency	1
VOCODER	Voice Encoder	29
WJHTC	William J. Hughes Technical Center	28

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Appendix A: NEXCOM Basis of Estimates

A. NEXCOM Basis of Estimates

A.1 General Provisions

The following assumptions applied to NEXCOM when computing the cost:

1. Life cycle costs and benefits accrue from 1998 to 2020.
2. All newly acquired VHF radios must be multimode capable.
3. The 24 control facilities identified for NEXCOM included the 21 ARTCC's, and the Hawaii, Guam and San Juan CERAP's.
4. 6,360 radios were used as the *most likely* number of radios required to convert all the RCAGs based on current en route assignments.
5. Six radios are necessary to support one ATC A/G frequency for a sector. The six radios include one main receiver, one standby receiver, one main transmitter, one standby transmitter, one backup emergency transmitter, and one backup emergency receiver.
6. The current 1998 FAA Frequency Data Base has approximately 1,060 frequency assignments for approximately 800 en route sectors.
7. Based on historical data, the growth rate of NAS frequency assignments was assumed at 4% per year. (This growth rate included A/G expansion projects as well as assignment growth resulting from other programs such as Towers, TRACONS and base closures.)
8. The growth rate for radios in the en route environment was based on a minimum estimate of one- percent, a most likely estimate of two percent, and a high estimate of three percent.
9. The number of remote sites housing radios was as follows: 717 RCAGs, 720 BUECs, 1,422 RTRs, and 1,854 RCOs.
10. New radios were assumed to provide, as minimum, current baseline capabilities (based on the Workload Information System).
11. It was assumed that some VHF radios would continue to operate in the 25 kHz DSB AM mode for the foreseeable future.
12. It was assumed that DO-178B did not apply to the ground system.
13. A dedicated one-for-one BUEC architecture was assumed to be in place prior to NEXCOM deployment.
14. Based on current trends in new site requirements, as well as anticipated changes brought about by Free Flight, it was assumed that new sites would continue to be required throughout the life of the NEXCOM program.
15. The numbers used for estimating expansion and replacement of older equipment later in the life cycle were based on the current Consolidated Facilities Expansion (CFE) Program history.

16. It was assumed that all current A/G VHF and UHF radios and RCE equipment must be maintained in operating condition until replaced.

A.2 Benefits Methodology

The following assumptions and methodology were used to calculate benefits.

1. Maintaining the current system requires that money be spent to acquire replacement parts and components, materials, labor, spares. It was assumed that a FAA benefit was valid to the extent that maintenance and operating costs can be avoided if a new system was installed.

2. It was assumed that when aircraft are delayed in congested sectors, they incur costs through extra fuel burn and other direct operating costs. These costs are reported to the FAA through a Form 91. Delay costs could potentially be avoided by dividing the sector into two sectors (resectorization). Resectorization requires that frequency assignments be made available to allow for an additional controller position.

   Projections of where future sector congestion is likely to occur were made based on aviation forecasts using an NAS-wide, macro simulation model (NASPAC). Estimates were made of the availability of frequencies to split the congested sectors based on the FAA ASR Frequency Assignment Data Base.

   Delay costs were estimated for sectors in which frequencies were unavailable. En route avoided delay costs represent a benefit to NEXCOM. The benefits of avoided delay costs must be offset by the costs of putting the new system into place. Resectorization requires additional controller positions, and associated growth in ground facilities. These costs were deducted from NEXCOM benefits.

3. Local airports have projected new runway construction and runway modifications. These proposed new runways and runway modifications are identified in the Airspace Capacity Enhancement Plan.

   Projections were made of the required number of positions and associated frequency assignments supporting the new runways. The FAA ASR Frequency Assignment Data Base was used to evaluate where frequency assignments are available to support the required operational positions for the new runways. If frequency assignments are not available to support new runways, then capacity benefits that would be realized through use of the new runways were assumed to not be available. Avoiding the loss of capacity represents a benefit for NEXCOM. This estimate presumed that there are no other factors that would hamper the construction of these runways/improvements.

4. Safety benefits, which accrue from a reduction of operational errors (OEs), near-miss air conflicts (NMACs), pilot deviations (PDs), and other similar problems, were identified and acknowledged but not quantified in the economic analysis.

5. Spectrum was assumed to have economic value. Private industry buys spectrum through submitting bids at Federal Communications Commission (FCC) Auctions. Based on bids for spectrum similar to FAA's spectrum band, an economic value (cost) can be placed on the FAA's spectrum shortfall. However, for the FAA, spectrum represents an opportunity cost, rather than an economic value. Spectrum would

have a realizable economic value only if it could be converted to money directly by FAA. The opportunity cost or economic value of spectrum was based on an evaluation of bids submitted at FCC Frequency Auctions. The value of spectrum was acknowledged but not quantified in the economic analysis

A.3 Basis of F & E Cost Estimates

Program Segments are as follows:

1. Segment 1 - (2002 - 2008) Conversion of High/Superhigh en route facility A/G radios from analog to digital voice capability. Segment 1 affects airspace at and above FL240.
2. Segment 2 - (2005 - 2010) Integration of Ground Network with data link service Build 2 in facilities already doing digital voice integration.
3. Segment 3 - (2010 - 2015) Transition of selected High Density Terminal Airspace (57 TDLS Airports and associated TRACONS)
4. NAS Sustainment - There is an underlying VHF and UHF sustainment program throughout all segments. Current VHF analog radios were replaced with multimode radios. Multimode radios must operate in analog mode where required. Current UHF analog radios was replaced with UHF analog radios.

The dates defining the three segments are as follows:

1. High/super high en route sectors voice only, 2002-2008.
   - Initial Operating Capability-analog: 10/02, Final Operating Capability-analog: 1/06
   - IOC-digital: 1/05, FOC-digital: 9/08. High/Superhigh digital voice was assumed to begin cut over to digital by 2005 and completed in 2008 (FOC Segment 1).
2. High/super high En Route sectors, GNI with Data Services
   - IOC: 10/05, FOC: 9/10.
   - High/super high data operational by 2010 (FOC Segment 2).
3. High Density terminal areas (57 airports),
   - IOC-analog and digital voice: 10/10
   - IOC-data: 4/11
   - FOC-everything in segment: 9/15.

A.3.1 General Radio Assumptions

1. All aircraft that currently use VHF analog communications in the high en route airspace were assumed to equip with digital radios.
2. Current FAA VHF analog radios was replaced on a one for one basis in Segment 1.
3. The allocated air/ground communications bandwidth will remain in place. Only an increase in available channels per frequency was assumed to be realized.
   - Controllers may share radios but not channels.
   - A channel was defined as one voice or data time slot.
   - One radio supports four channels.

- Operational channel use of two voice/two data.
- Channel assignments were made on the basis of one voice channel and one data channel per controller.
- A radio was defined for costing purposes as either a transmitter or receiver.
- A radio pair was defined as a transmitter and receiver for costing purposes.
- Radio Interface Unit (RIU) was NOT considered part of the radios for costing purposes.
- The Vocoder was part of the Radio Interface Unit (RIU) (i.e., not separate from the RIU).
- One RIU was assumed for both main and standby transmitter/receiver pairs (4 radios). For BUEC sites, one RIU for each transmitter/receiver pair was assumed.

A.3.2 Segment 1

Segment 1 was to be implemented without a change to the existing Ground Network Infrastructure (GNI).

Equipment Cost Estimates:

- Current VHF Transmitter/Receiver pair - $8K (average $4K per unit)
- UHF Analog Transmitter/Receiver pair - $10K (average $5k per unit)
- Multimode Radios Transmitter/Receiver pair:
  - Low ---------- $9K (roughly a 10% increase over analog)
  - Most Likely - $12K (average of $6K per unit - represents increased transmitter costs that are greater than the decreased receiver costs)
  - High --------- $13K (roughly a 60% increase over analog)
- RIU:
  - Low ---------- $4K
  - Most Likely - $6K (provides for an RIU with significant increase in functionality over a remote RCE; includes Vocoder)
  - High --------- $8K (worst case estimate)

A.3.3 Segment 2

Ground Network Infrastructure required data capability.

1. The GNI were analyzed for two options: (a) Voice and data GNI, and (b) Data-only GNI.
2. Segment 2 required an additional TELCO path per RCAG and BUEC.
3. Equipment Cost Estimates:

   - GNI (Data only):
     - $50KCenter (84 radio capability)
     - $50K TRACON
     - $50K Tower
   - GNI (Voice and data).

- Level 1 - Centers and Large TRACONS (84 radio capability):
  - ⇒ Low ---------- $300K
  - ⇒ Most Likely - $400K
  - ⇒ High ---------- $450K
- Level 2 - TRACON (Small):
  - ⇒ Low ---------- $35K
  - ⇒ Most Likely - $50K
  - ⇒ High ---------- $85K
- Level 3 - Tower:
  - ⇒ Low ---------- $36K
  - ⇒ Most Likely - $60K
  - ⇒ High ---------- $100K

- Emergency Transceiver (ETR) - $6k.

A.3.4 Segment 3

There is one GNI per high-density terminal airspace and ATCT.

A.3.5 Other Supporting Cost and Assumptions

1. Each site required a timing source (e.g., atomic clock or GPS receiver) that synchronizes primary and diverse sites. The cost per site was estimated to be $2K.
2. Training costs were estimated from previous FAA program history
3. Disposal costs were estimated to be 1% of Prime Mission Equipment (PME).
4. Program Management costs was estimated to be 12 percent of PME.
5. Remote site infrastructure upgrades were 5% of PME for Segment I.
6. Remote site infrastructure upgrades were 15% of PME for Segment III.
7. The transition team provided actual numbers for installation and site activation.
8. Radio warranties were assumed to begin upon delivery (10-year warranty).
9. It was assumed that an extended warranty might be negotiated for years 11-20 of life cycle, for lower cost than the cost of purchasing a new radio.
10. Initial spares were estimated at 10% of PME.
11. Cost of ancillary equipment was estimated at 10% of Total Prime Mission Equipment (PME). LPA equipment was added.
12. Manpower costs for system implementation were estimated using FAA program historical costs.

13. En Route analog radios (RCAGs and BUECs) were replaced on a one for one basis.

14. RCAGs had main and standby radio sets. Diverse site (BUEC) had single set of radios (i.e., no standby radios).

15. Emergency Transceivers (ETR) were assumed capable of VHF Analog, UHF Analog and VHF TDMA.

16. Serviceable antennas, towers, racks, cabling, and other ancillary equipment were retained and used with the new system.

Additional ancillary equipment was added only to support equipment in excess of the current system.

A.4 Basis of O&M Cost Estimates

The following was the basis of the O&M cost estimates.

1. Direct work staffing was based on Workload Information System for RCAG, RCO, RTR and BUEC facilities.

2. Leased telecommunications costs were based on telecommunications costs for RCAG, RCO, RTR and BUEC systems found in the Telecommunications Information Management System database. Costs for the new sites were estimated using average costs for an RCAG.

3. Cost of leases was estimated using the lease costs from the Real Property Record Systems for RCAG, RCO, RTR and BUEC systems. Lease costs for the new sites were estimated using the average costs for an RCAG.

4. Utilities and other site costs were estimated using costs for RCAG, RCO, RTR AND BUEC facilities found in the rent, utility, and Other Facility Costs Study.

5. FAA Logistics Center costs and the FAA Logistics Center and AOS provided second level engineering costs for the baseline radios.

6. Recurring training costs for AMA provided the baseline radios. Training costs for NEXCOM were estimated using a factor on initial training costs.

7. Contractor support costs for the baseline radios were based on contractor support costs for the present air-to-ground radio program.

A.5 Basis of User Avionics Costs

The following was the basis of the cost estimates for airborne avionics using a 20 percent discount off estimated vendor list prices.

A.5.1 Cost per aircraft was developed for each of six basic user categories:

1. air carrier: digital

2. air carrier: non-digital

3. regional/commuter/corporate general aviation: digital

4. regional/commuter/corporate general aviation: non-digital
5. low-end general aviation
6. military

It was estimated that approximately 50 percent of the air carrier and 50 percent of the regional/commuter/corporate general aviation fleet would be digitally capable. Non-digitally capable aircraft require additional equipment and expense compared with digitally capable aircraft in order to obtain VDL Mode 3 capability.

A.5.2 Basic Avionics Costs

For the Preferred Alternative (VDL-3) components and hardware cost included for each user category, are indicated below:

1. air carrier: digital - 3 VHF digital radios ($25,200 per radio)
2. air carrier: non-digital
   - 3 VHF digital radios $25,200 per radio
   - 2 CMUs $25,600 per CMU
   - 1 cockpit display unit $11,600 per unit
   - 1 vocoder $8,000 per unit
3. regional/commuter/corporate general aviation: digital - 2 VHF digital radios -$12,800 per radio
4. regional/commuter/corporate general aviation: non-digital
   - 2 VHF digital radios $12,800 per radio
   - 2 CMUs $16,000 per CMU
   - 1 cockpit display unit $11,600 per unit
5. low-end general aviation - 1 VHF digital radio ($1,600 per radio)
6. military (average cost per aircraft)
   - VHF digital radio(s) - quantities vary by specific aircraft type - $48,000
   - control heads - $3,000

A.5.3 Avionics Installation and Spares

1. Software upgrade to CMU for digitally capable air carrier and regional/commuter/corporate general aviation - $1,600 per CMU
2. Digital radio wires - $40 per wire
3. Installation - $65 per hour for all aircraft except military; $85 per hour for military aircraft
4. Out-of-service cost for non-digitally capable regional/commuter aircraft - $6,600 per aircraft

Hardware spares - 15% additional hardware for air carrier and regional/commuter aircraft; 20% additional hardware for military aircraft

A.5.4 Aviation Certification Costs

Supplemental Certification Cost (STC) for air carrier and regional/commuter aircraft

- digital radio $25,000
- cockpit display unit $50,000
- CMU $25,000

Certification cost for STC were calculated for air carrier and regional/commuter aircraft.

Total certification cost were estimated by multiplying the estimated certification cost per unit of equipment times the estimated number of times the equipment would need to be certified. Total certification costs were estimated by user category in Table A-1.

Table A-1. Total Certification Costs

User Category	Cost
air carrier: digital	$1,625,000
air carrier: non-digital	$6,500,000
regional/commuter: digital	$1,750,000
regional/commuter: non-digital	$7,000,000

These costs were allocated over the first four years of the equipage period for each relevant user category.

A.5.5 Avionics Cost Methodology

The basic methodology for deriving the cost estimates for each user category for each year was to multiply the following components:

- Equipage cost per aircraft.
- Total number of aircraft to be retrofitted.
- Equipage rate.

In the case of air carrier and regional/commuter aircraft, costs were added for certification. In the case of non-digital regional/commuter aircraft, costs were also added for out-of-service time.

Out-of-service cost was included for non-digital regional/commuter aircraft.

These costs were calculated based on the average revenue per day per aircraft multiplied by the estimated percentage of revenue foregone (20 percent) multiplied by the estimated number of days the aircraft would be out of service beyond the regular maintenance cycle (three days). This equals an estimated $6,600 per aircraft for out-of-service time. It was assumed that retrofits for other commercial aircraft could be accomplished within the regular maintenance cycle and therefore no out-of-service costs were included.

$11,000
x .2
x 3
$6,600

Equipage for TDMA was assumed to begin in 2003 and equipage rates were applied to the total number of aircraft in each category in 2002. The equipage rates by user category are depicted in Table A-2.

Table A-2. Equipage Rates

User Category	Equipage Rates
Air carrier, Regional/Commuter Military, and Corporate GA	2003 - 2008: 15% per year - completed: 2010
Other radio-equipped GA	2003 - 2015: 5-10% per year completed: 2015
Overall GA	2003 - 2015: 5-10% per year 94% in 2015

The GA fleet was assumed to be 94 percent radio equipped.

An estimated six-percent of GA is not currently radio equipped and it was assumed they would not equip in the future. Approximately five percent of the general aviation fleet are corporate.

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